A First Look at Systematic Uncertainties in a 12 GeV Moller Experiment

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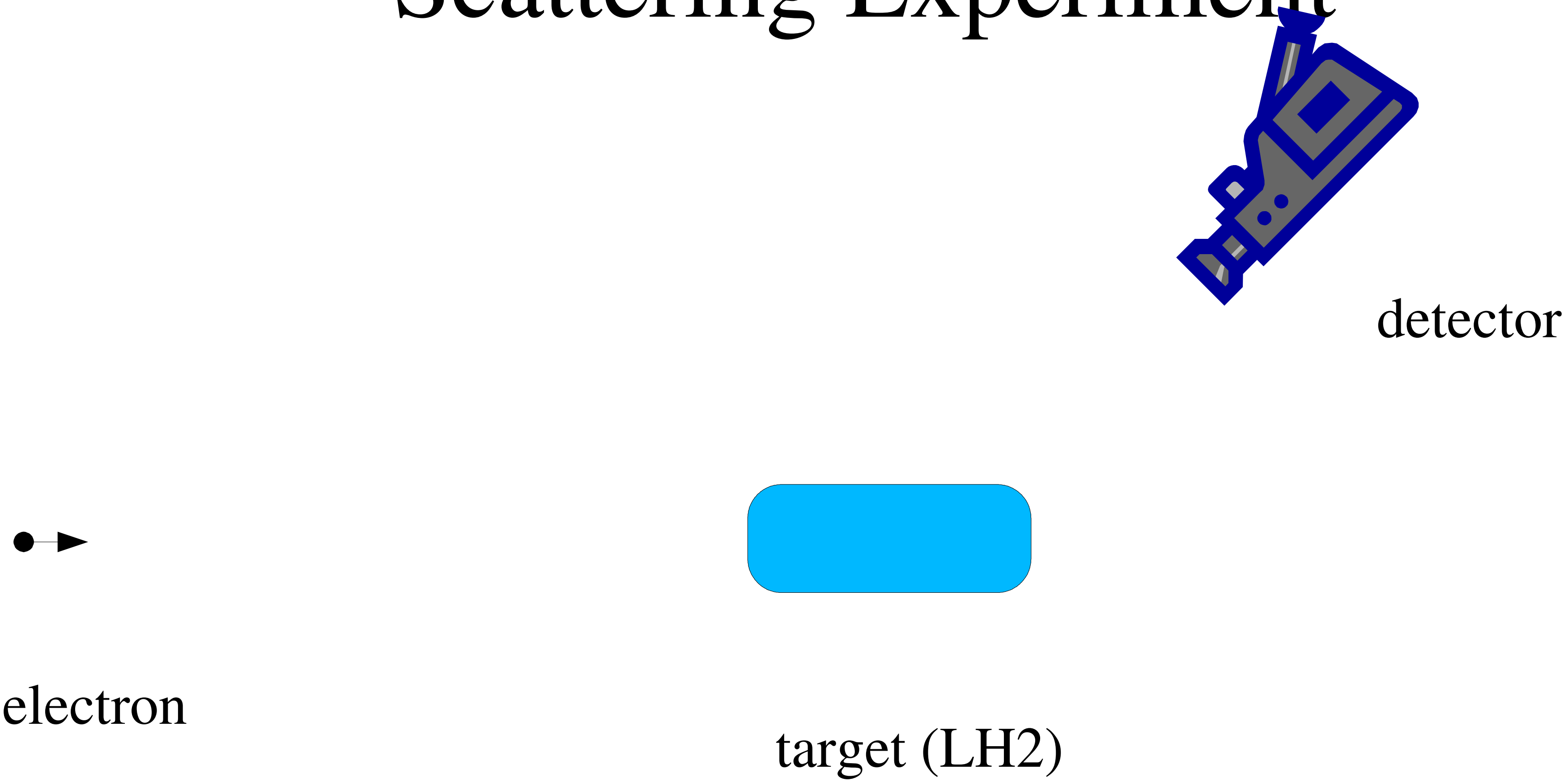
D. Mack – Jefferson Lab
presented by J. Martin – University of Winnipeg

Generic Parity Violation Scattering Experiment



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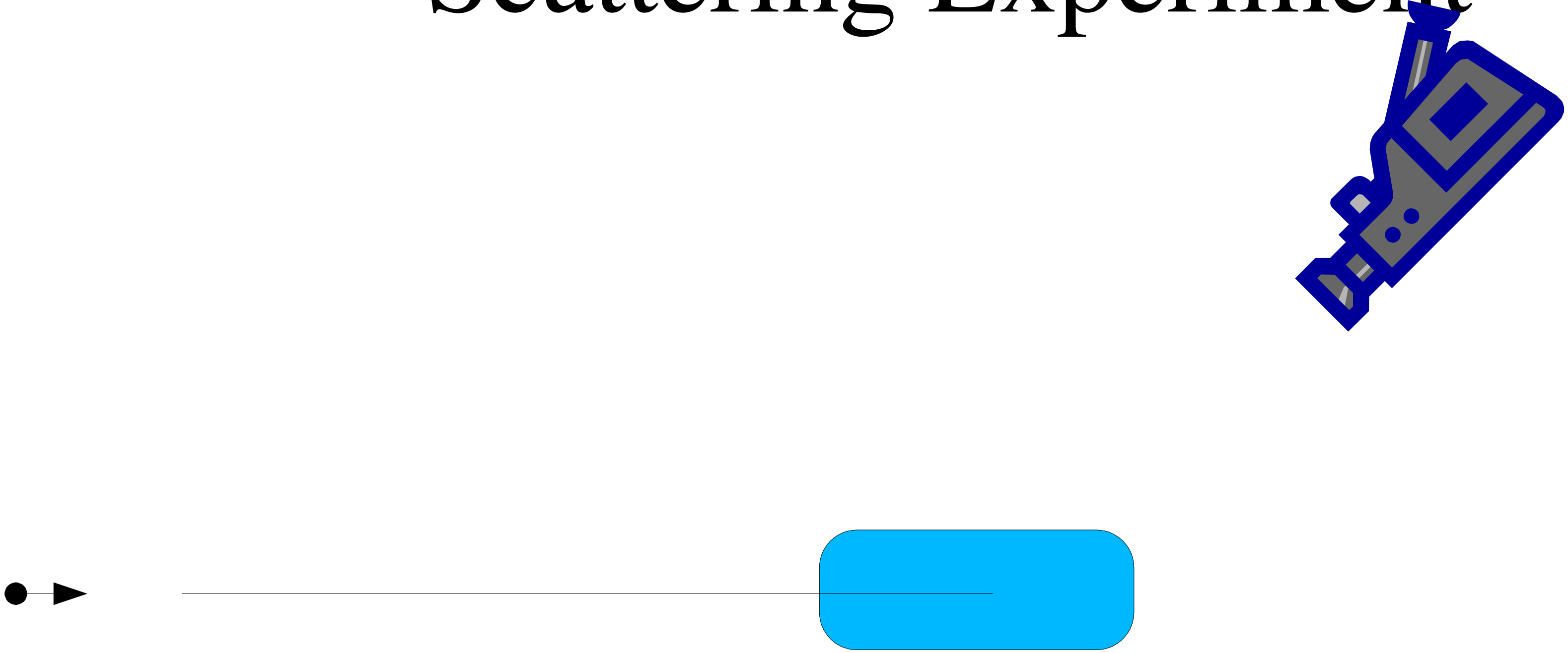

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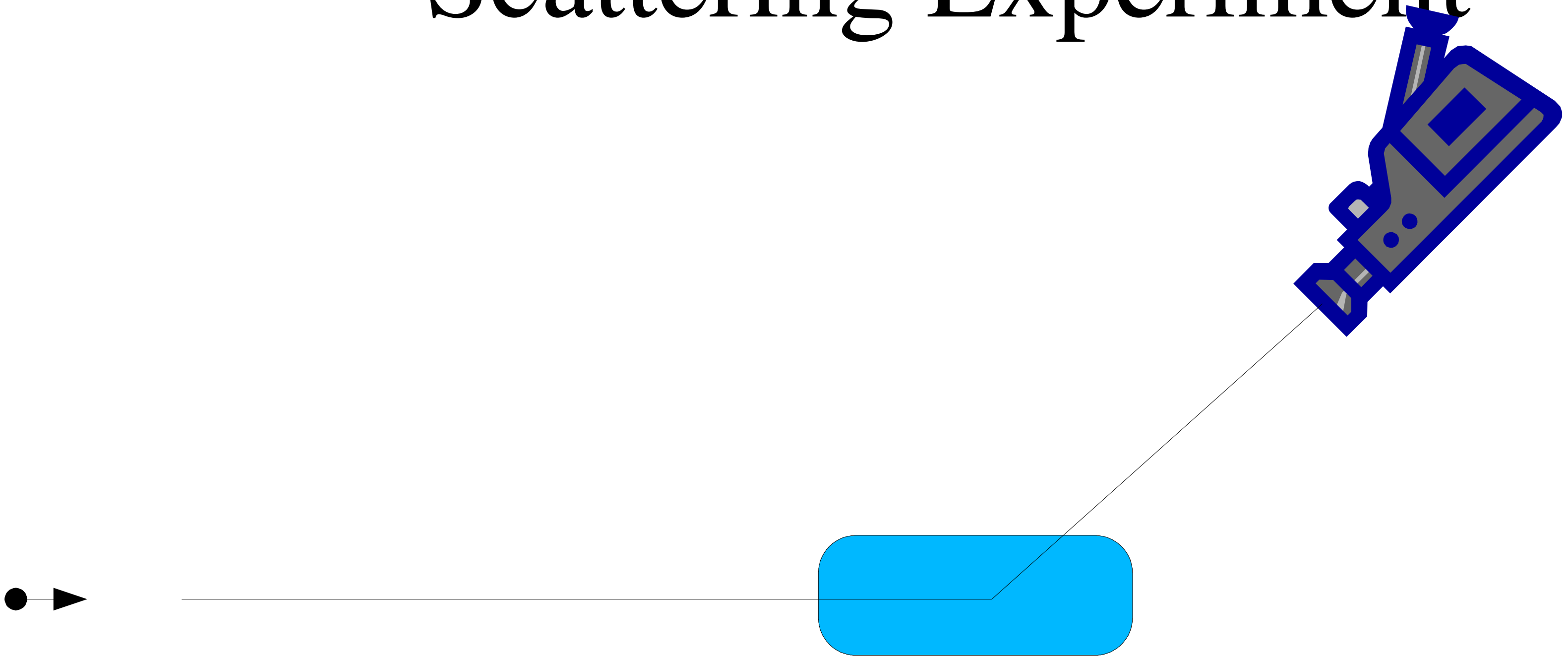

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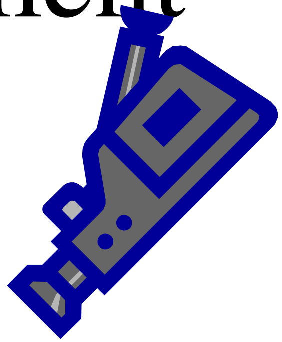
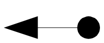
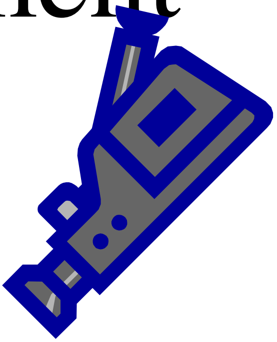




parity-reversed experiment

Generic Parity Violation Scattering Experiment



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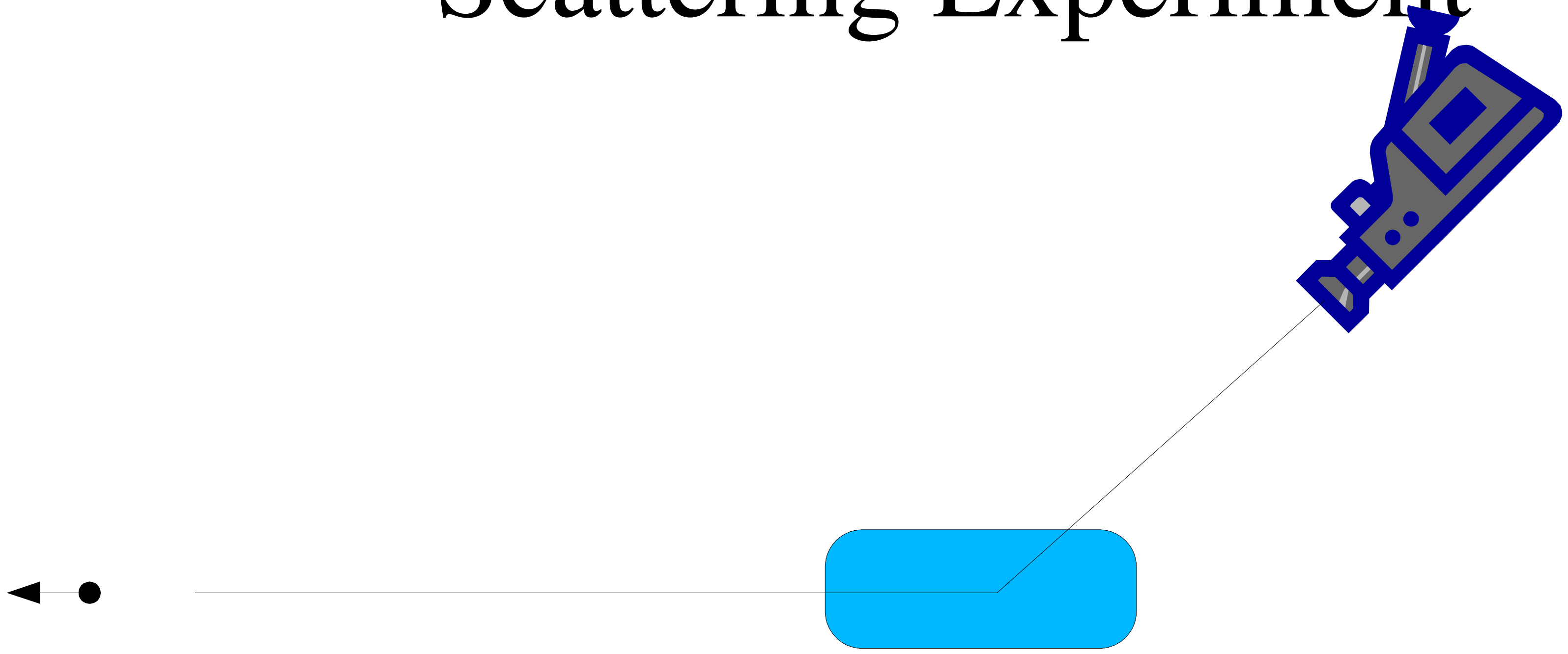

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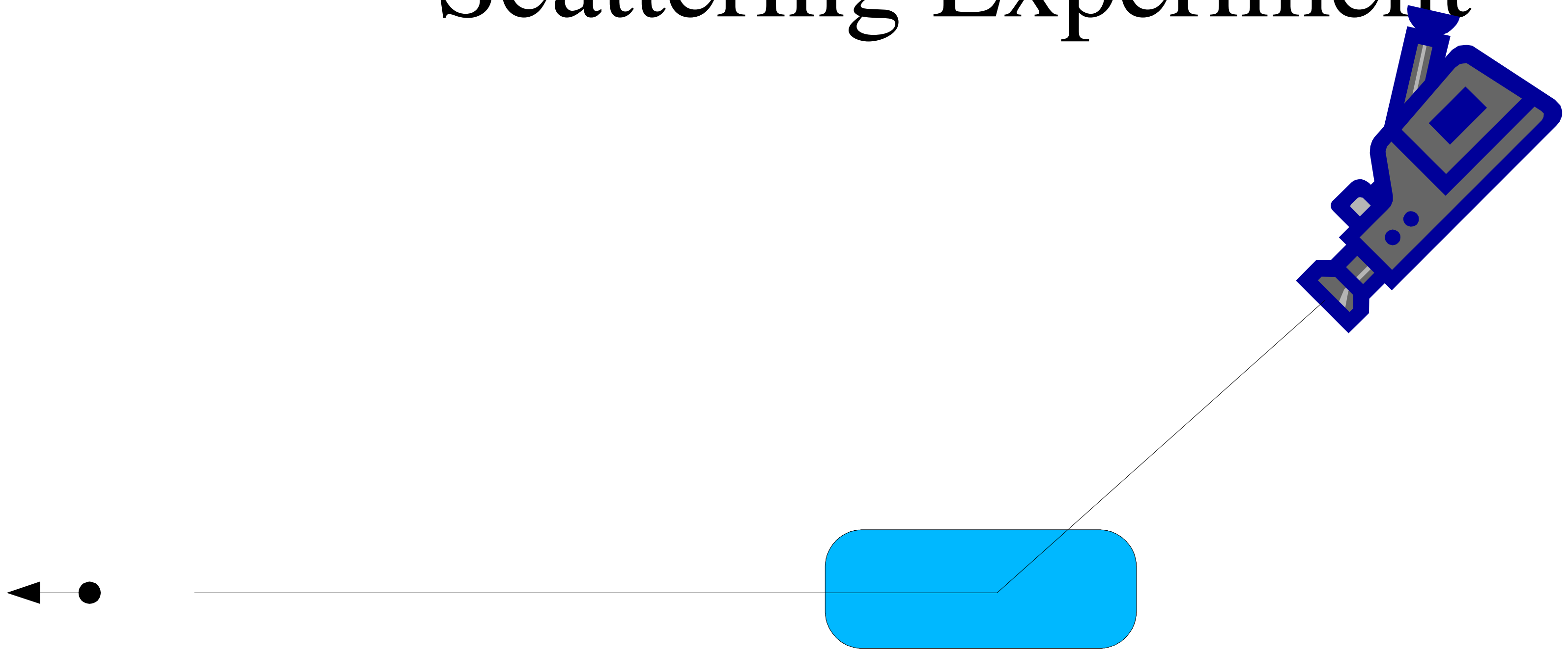
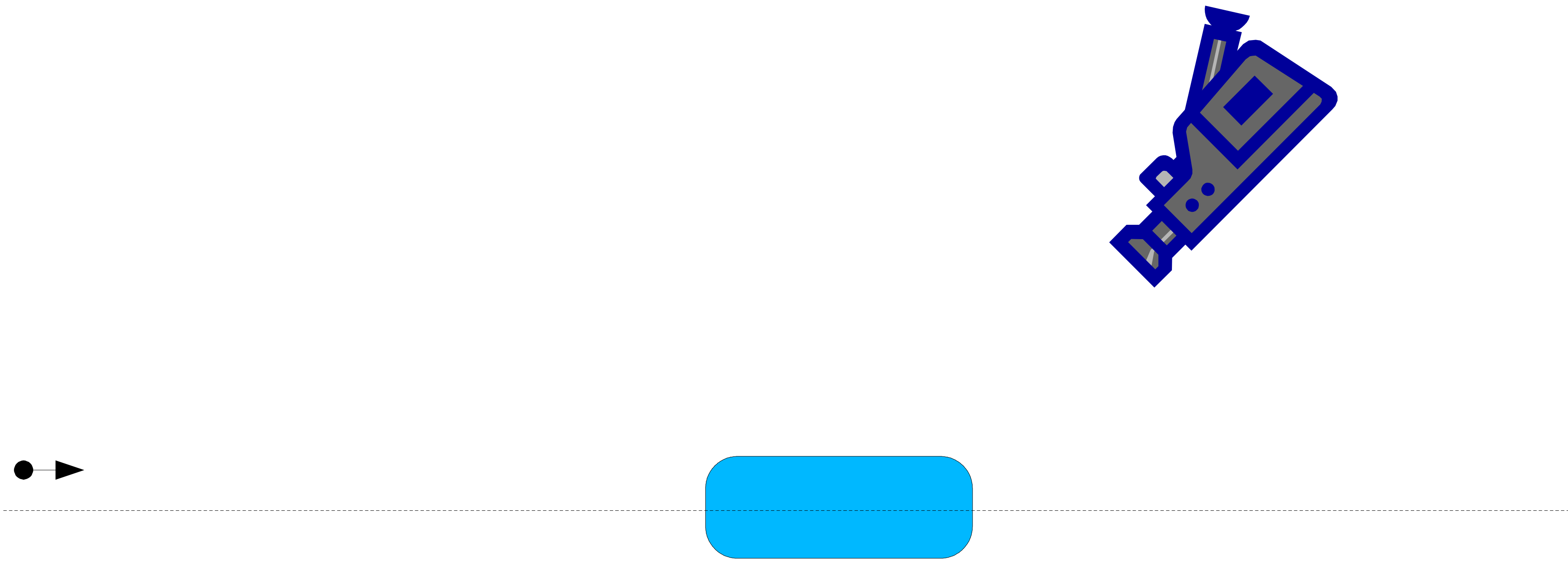


These experiments are the same to 10^{-7}

Helicity-Correlated Systematics



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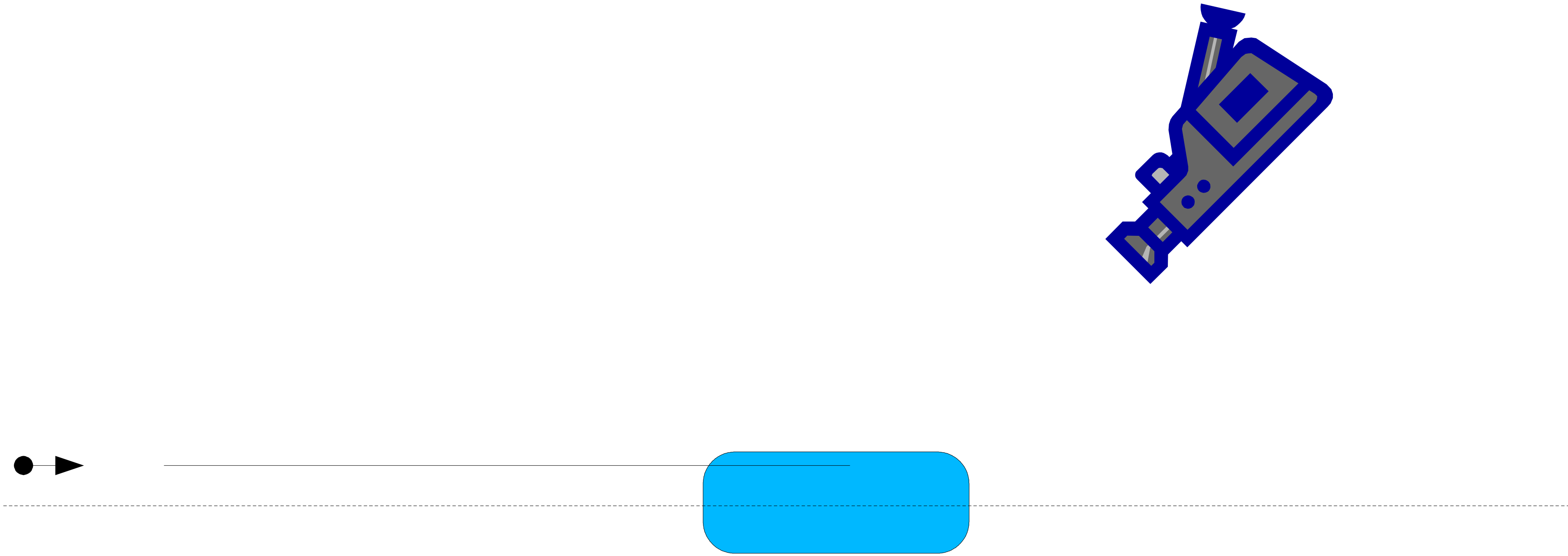

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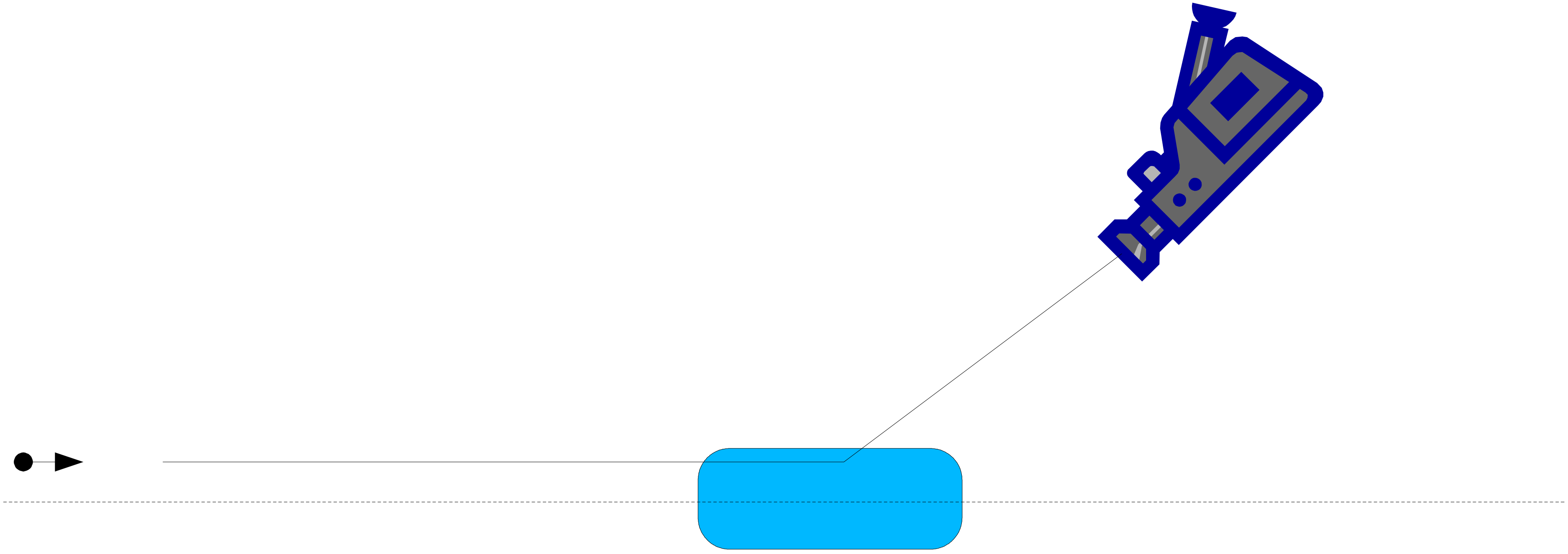

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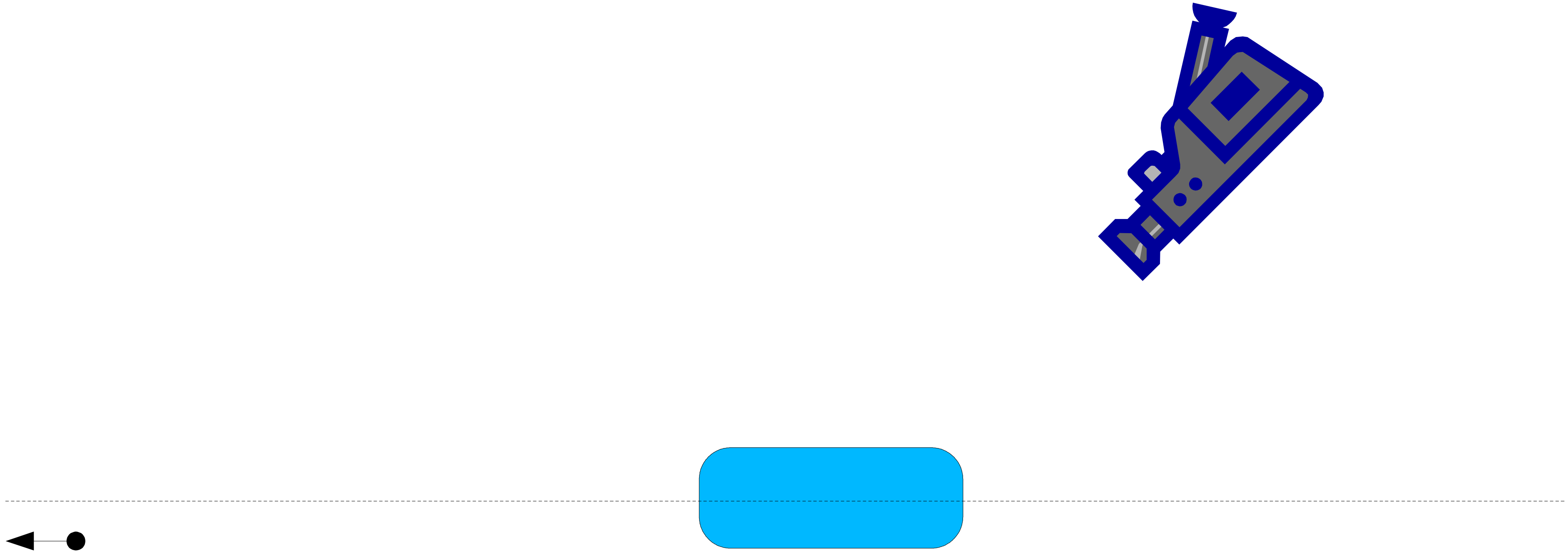

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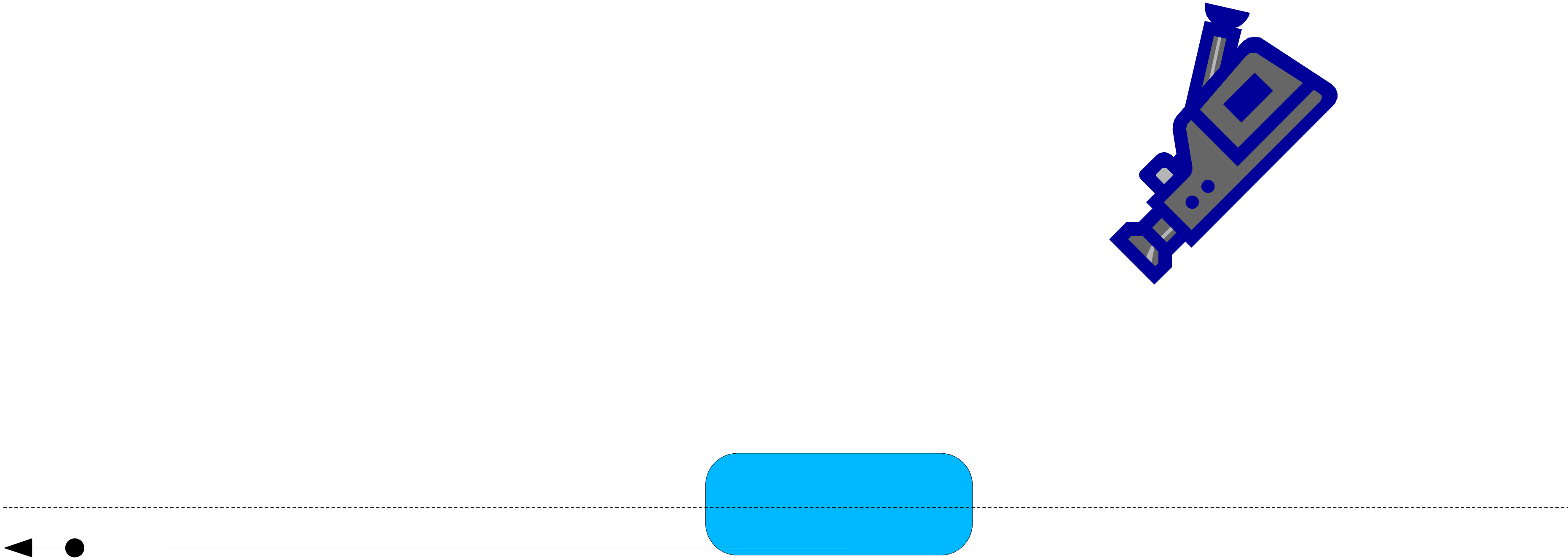

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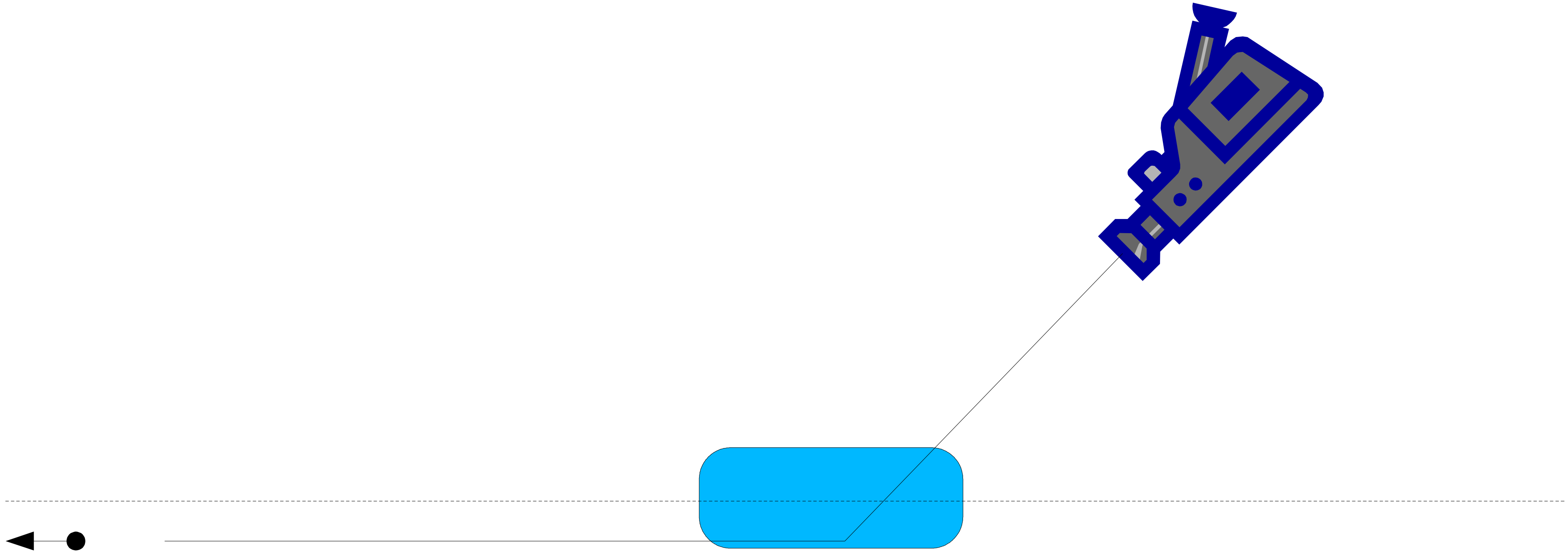

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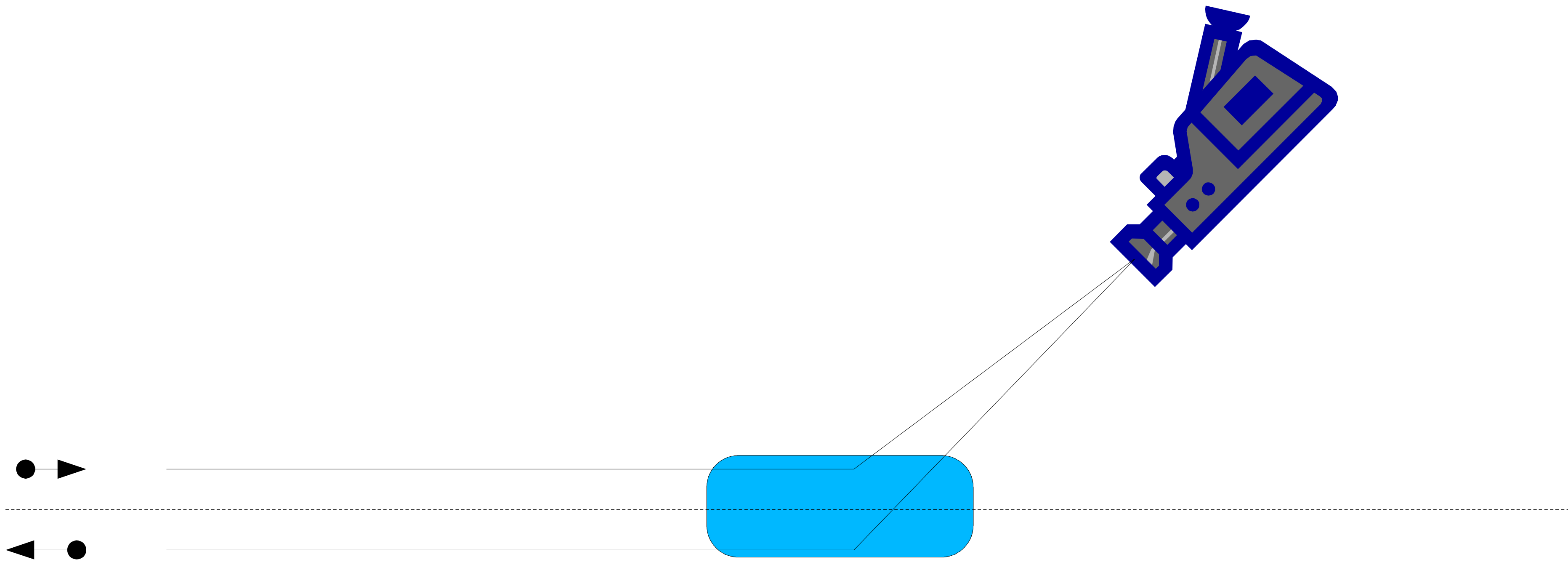

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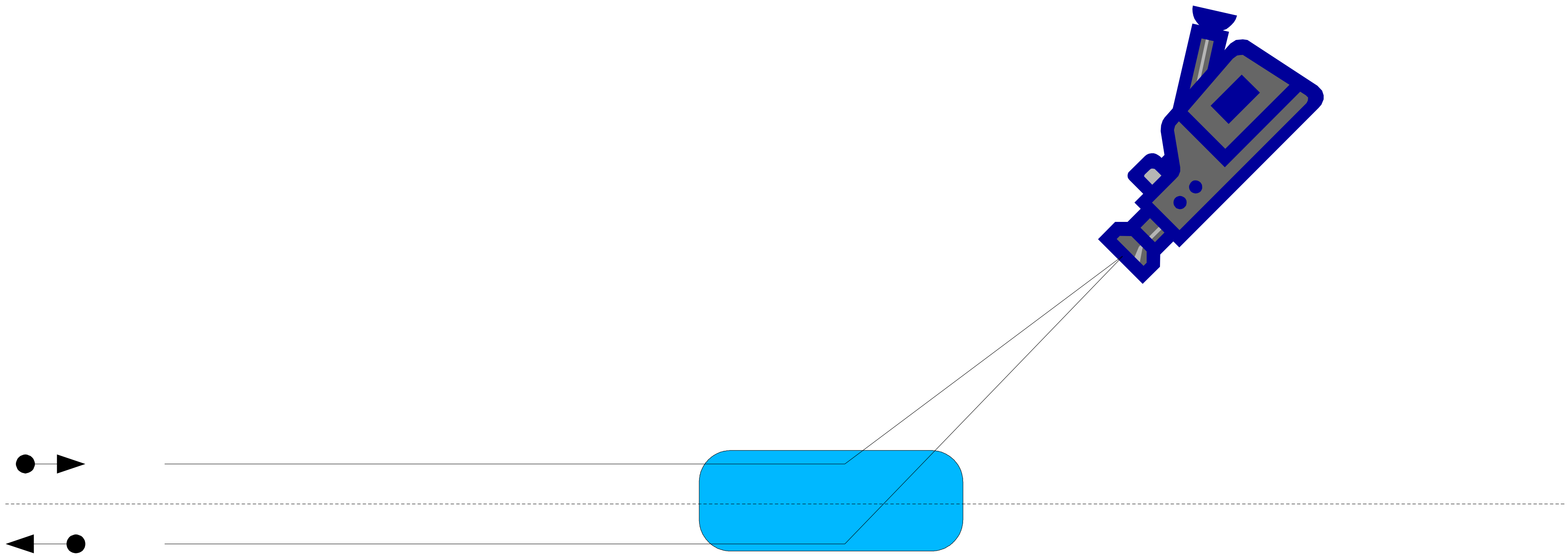
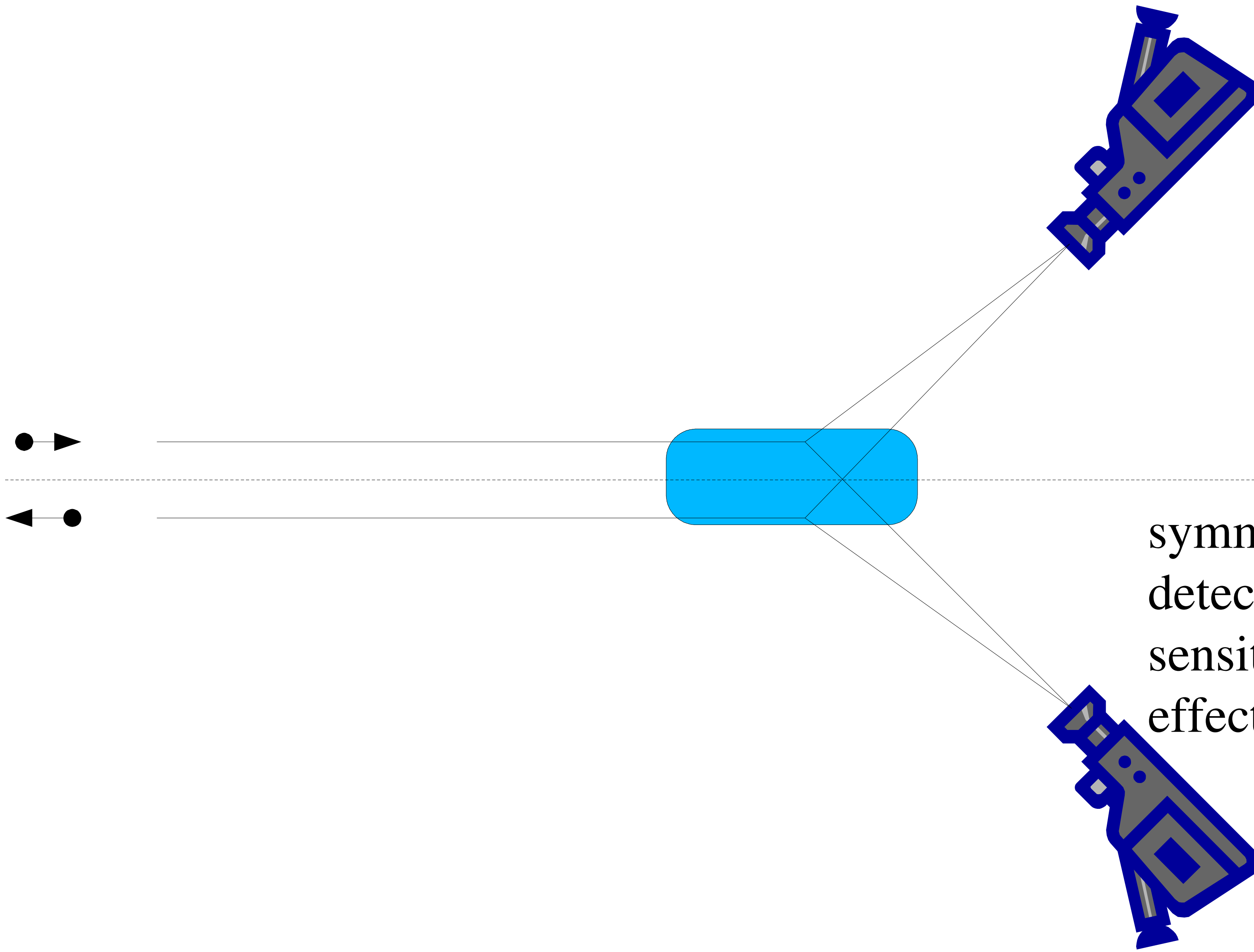


must have excellent control of all
“helicity-correlated” beam properties
(see G. Cates' talk)

Helicity-Correlated Systematics



symmetry in
detector to minimize
sensitivity to this
effect

Sensitivity to Helicity-Correlated Effects

- This is why most parity-violation experiments have some degree of symmetry in the detector.
- There is a limit to how much symmetry in the detector can do for us.
- Jim did a Monte Carlo simulation to give a first look at these issues (based on experience from G0 and Qweak sims)

Parameters for the simulation, from Dave Mack

Parameter	**12 GeV JLab**
E	12 GeV
E'	3-6 GeV
$<Q^2>$	0.008 (GeV/c)^2
θ_{lab}	0.53^o - 0.92^o
Current	100 μA
Target Length	150 cm
Collimator	5 m downstream from target
False Asymmetry	< 10^{-9} from each source

Systematic Error Simulations

Sensitivity to:

Motion of beam on target

Beam breathing

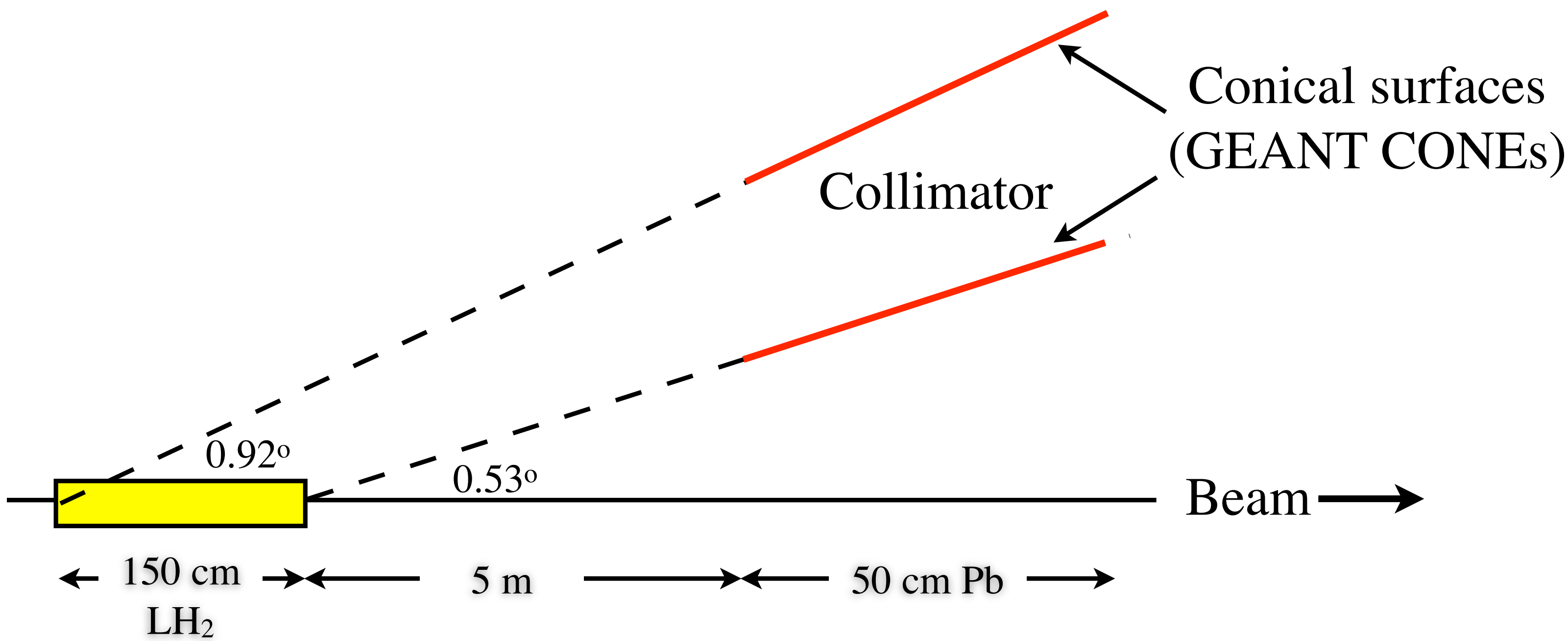
Angle of beam on target

Energy modulation

No magnet!

A Simple Collimator

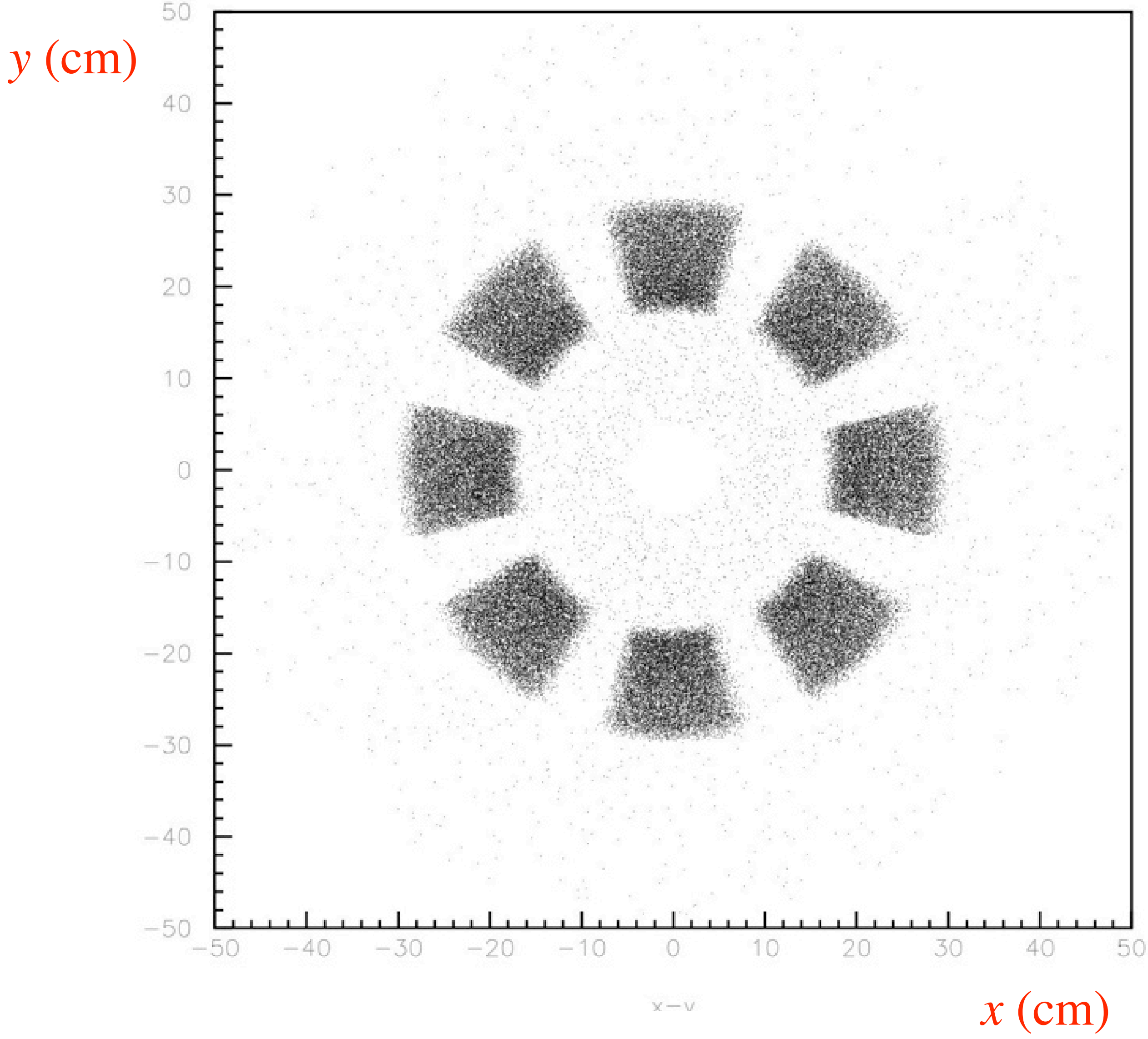
(NOT optimized, diagram NOT to scale)



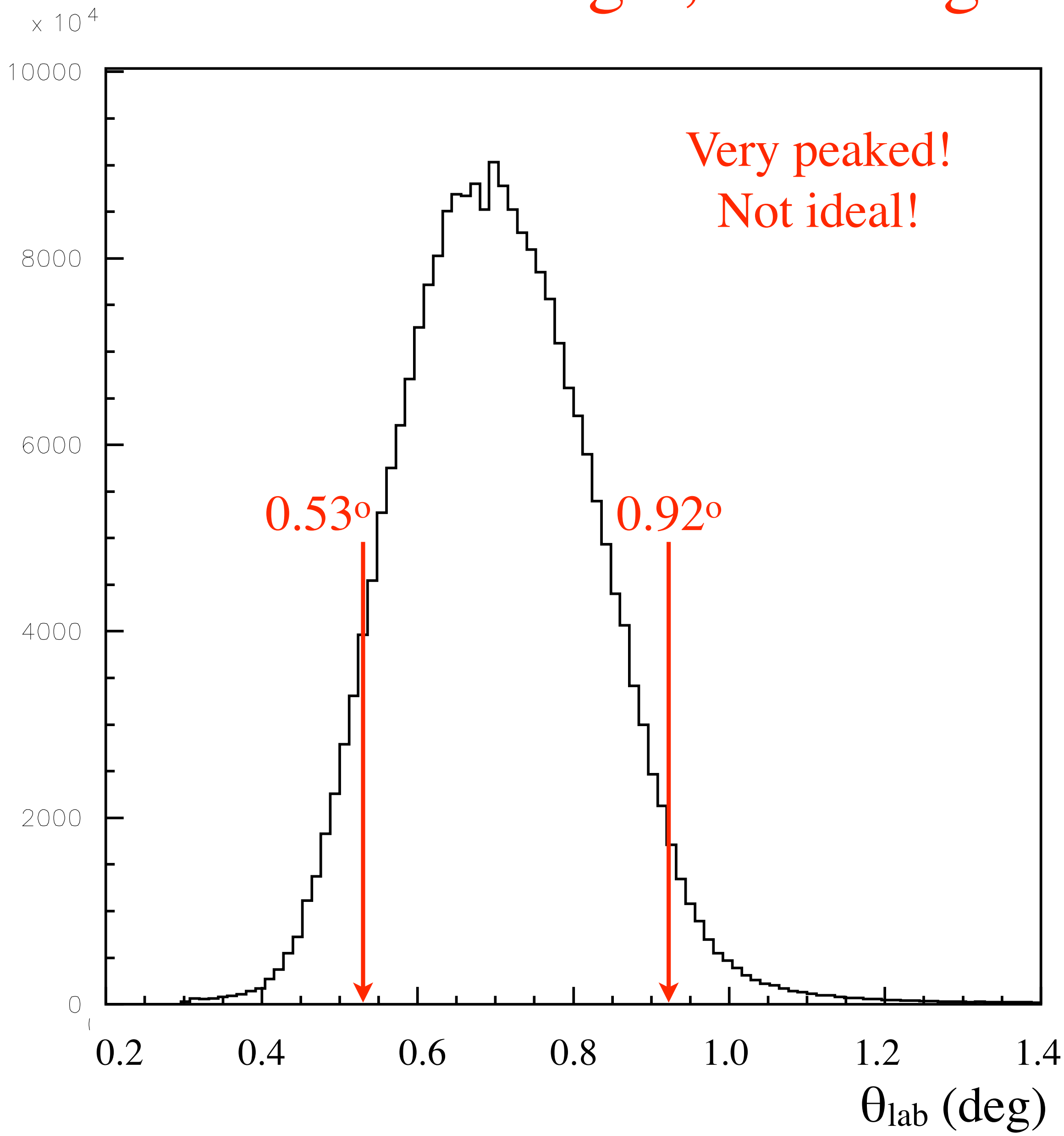
Detector:

- A plane 10 m downstream from centre of target, uniform response, that captures Moller electrons that passed through the collimator
- Find variation of event rate with position, direction, energy of beam on target...

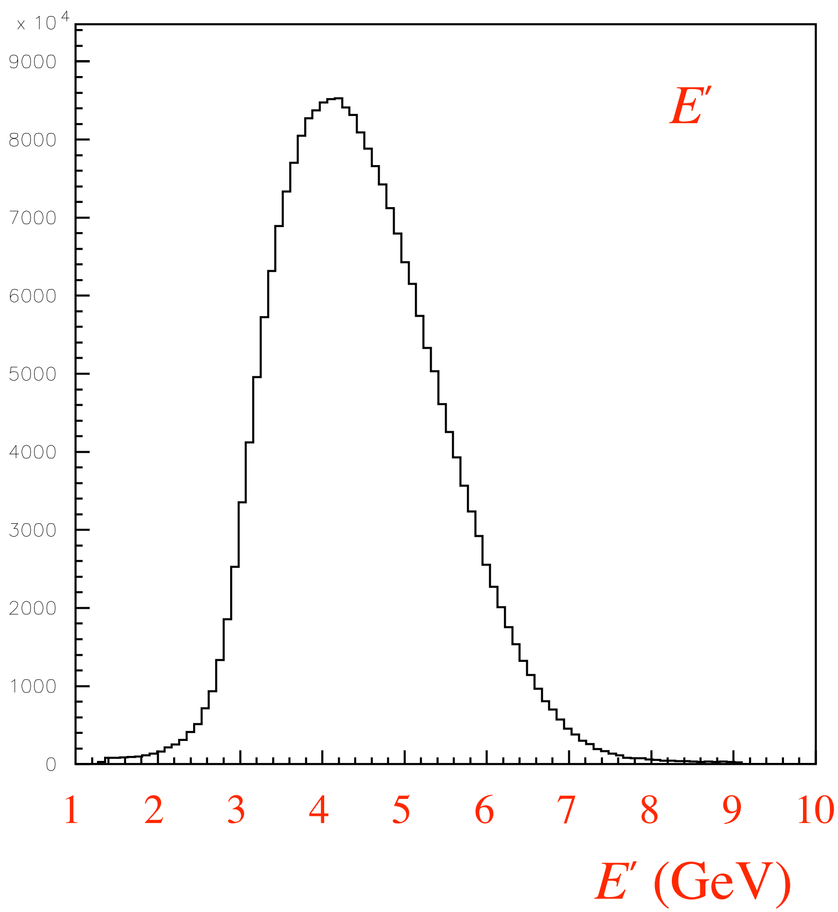
Moller electrons at detector plane (no magnet!)



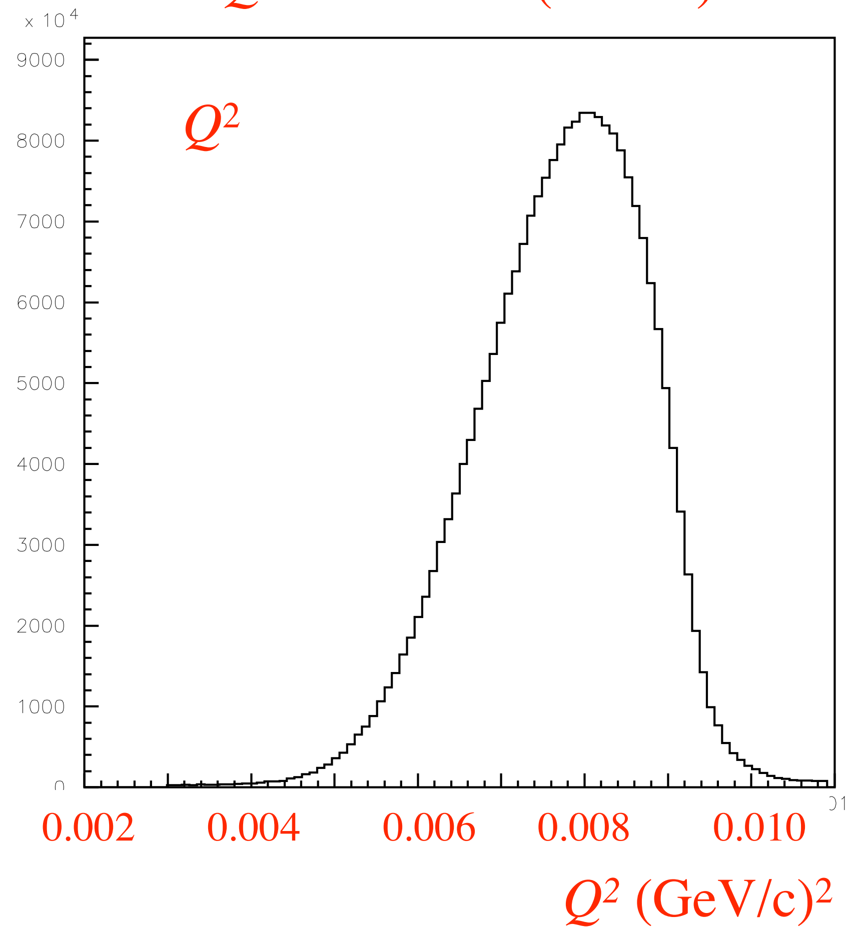
Angle of scatter from target, not weighted by rate



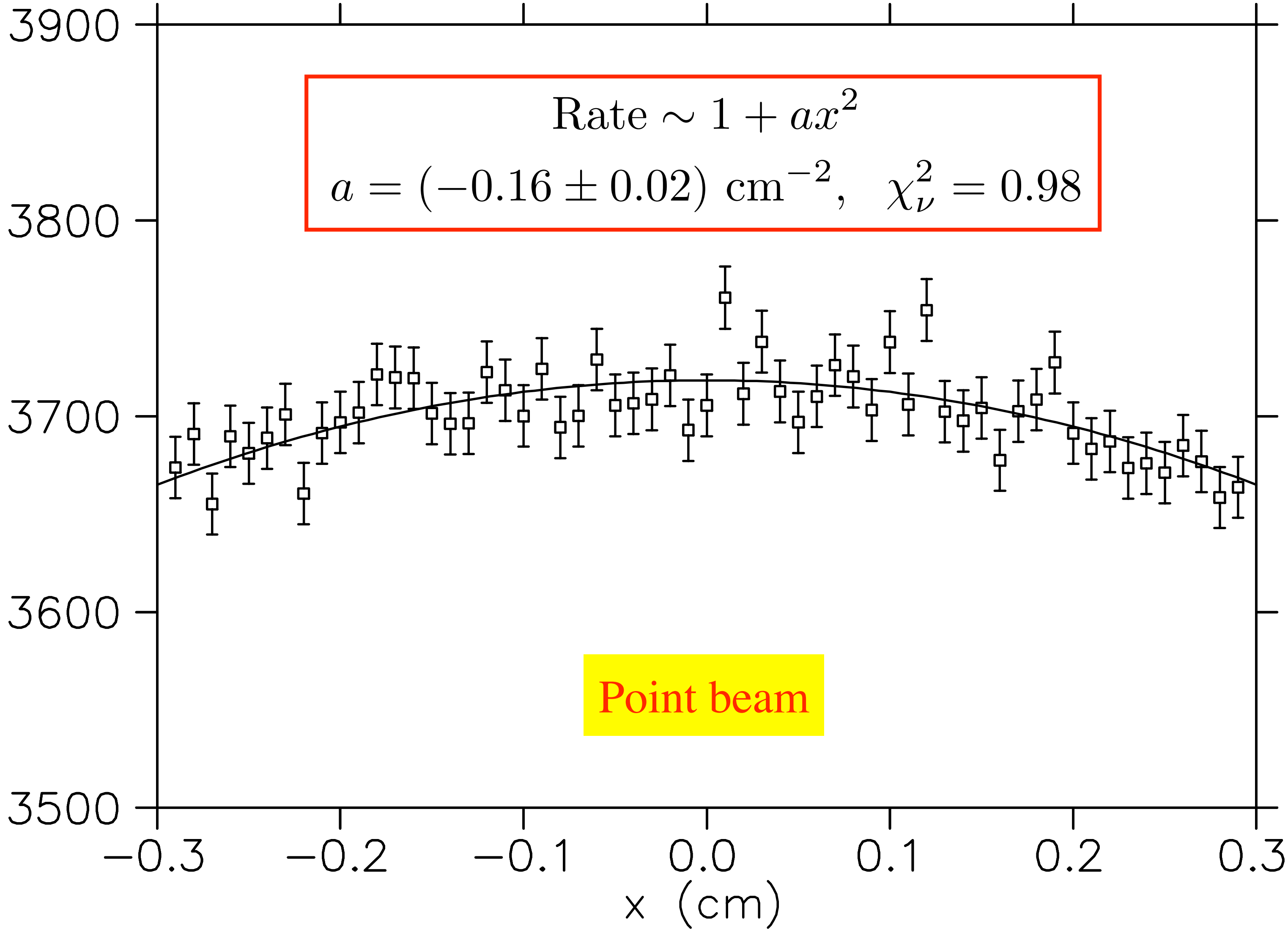
Moller Electrons, weighted distributions



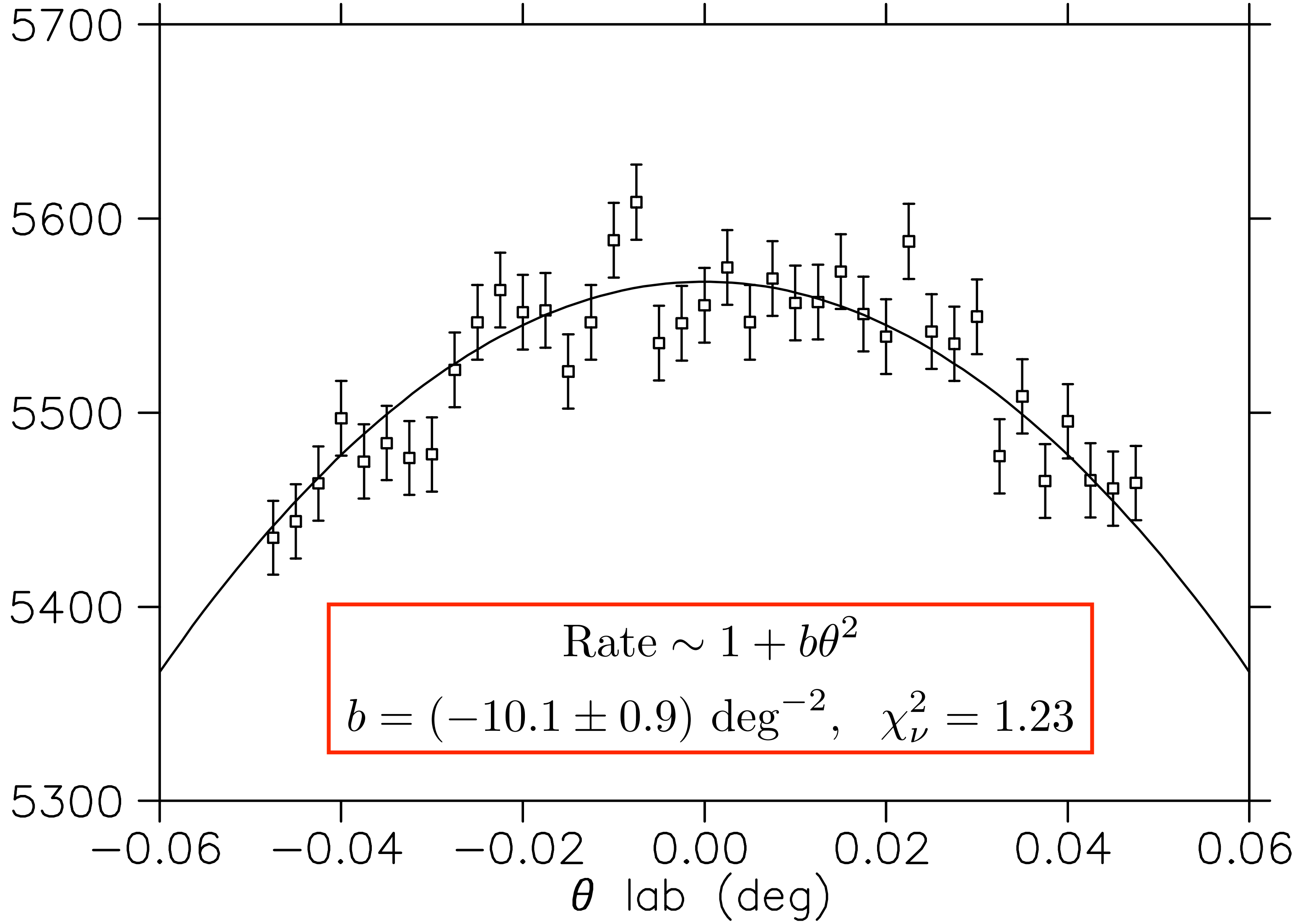
$\langle Q^2 \rangle = 0.0077$ (GeV/c)^2



Rate as function of position of beam on target



Rate as function of angle of beam on target



Systematic Errors

Beam Position: $x^{\pm} = x_0 \pm \delta x$, with rate $\sim 1 + ax^2$, $a = -0.16 \text{ cm}^{-2}$

False asymmetry, $\epsilon = 2ax_0\delta x$

Beam Breathing: integrate rate over beamspot, keeping beam current fixed

$$\text{Rate} \sim \frac{\int_0^{r_0} 2\pi r(1+ar^2)dr}{\int_0^{r_0} 2\pi r dr} = 1 + \frac{ar_0^2}{2}$$

False asymmetry, $\epsilon = ar_0\delta r$, $r^{\pm} = r_0 \pm \delta r$

Angle modulation: for rate $\sim 1 + b\theta^2$ and $\theta^{\pm} = \theta_0 \pm \delta\theta$

False asymmetry, $\epsilon = 2b\theta_0\delta\theta$, $b = -10 \text{ deg}^{-2}$

Energy modulation: $\frac{1}{\sigma}\frac{d\sigma}{dE} = -0.046 \text{ GeV}^{-1}$, $E^{\pm} = E_0 \pm \delta E$

False asymmetry, $\epsilon = -0.046\ \delta E$

Beam Requirements

Cause of error	Condition for $\varepsilon < 10^{-9}$	Example
Position modulation $x^{\pm} = x_o \pm \delta x$	$x_o \delta x < 3.1\times10^{-9}$ cm^2	$\delta x = 20$ nm $x_o = 16$ μm
Beam breathing $r^{\pm} = r_o \pm \delta r$	$r_o \delta r < 6.3\times10^{-9}$ cm^2	$r_o = 75$ μm $\delta r = 8$ nm
Angle modulation $\theta^{\pm} = \theta_o \pm \delta\theta$	$\theta_o \delta\theta < 5\times10^{-11}$ deg^2	$\theta_o = 60$ μrad $\delta\theta = 0.3$ nrad
Energy modulation $E^{\pm} = E_o \pm \delta E$	$\delta E < 22$ eV	$\delta E < 22$ eV

Conclusion

- Based on this work
  - beam requirements are not “crazy”, by JLab standards.